

Mini-Bias and Underlying Event Studies at CMS

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1 Introduction

The Tevatron experiments provide us very good information for the quantum chromodynamics (QCD) modelings of event generators. However, in the LHC era, the collisions is in different region of phase-space from that of Tevatron. A naïve rescaling of cross-sections will not work. The current modeling of non-trivial interplay of perturbative and non-perturbative aspects based on Tevatron data have large discrepancies when extrapolated to the LHC energy. This study is devoted to the proton-proton dynamics exploration: discriminating among different QCD Monte Carlo models.

2 The Minimum Bias events and triggers

From the experimental point of view, a minimum bias events (MB) correspond to a non-single diffractive inelastic interaction. Meanwhile a totally inclusive trigger, or called zero bias trigger, corresponds to a randomly reading out from the detector whenever a collision is possible. The later is only efficient when the luminosity is high enough such that a reasonable probability of collisions occur during a bunch crossing.

For events with one and only one collision occurs is called “ideal data”, which have no piled-ups, during a bunch crossing. This kind of events is important for underlying events (UE) study as no influence from multiple p-p interactions.

The average number of collisions, constituting the pile-up, per beam bunch can be described as:

$$\langle N_{int.} \rangle = L_{inst.} \times \sigma / f_{rev.}$$

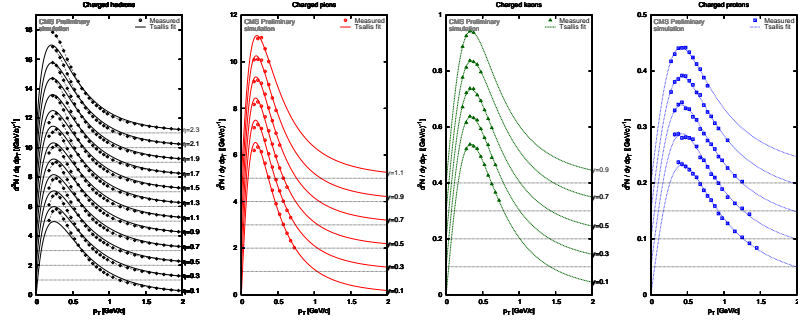
The cross-section σ , includes both elastic and inelastic, is ~ 100 mb at LHC with mostly low p_T particles and low multiplicity. So the averaged number is about 35 events per bunch-crossing for luminosity $L=1034 /cm^2/sec$.

2.1 Minimum-Bias Trigger

The MB trigger in CMS is using the Hadron Forward (HF) calorimeter. It has a geometrical coverage from 3 to 5 in absolute value of pseudo-rapidity η and consists of 18 wedges per side with tower size 0.175×0.175 in η and ϕ . A trigger based on minimum 10 towers with energy threshold greater than 1.4 GeV gives 90% efficiency.

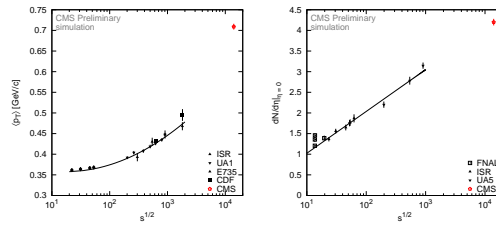
2.2 Charged Hadron Spectra

A study on the charged hadron spectra on MB events has been performed. The measured differential yields of unidentified charged particles as well as pions, kaons and protons are shown as a function of p_T and in narrow η bins. Tsallis function fits are also superimposed. The results are using a sum of both positive and negative charged particles and assuming symmetric η bins.



2.3 Energy dependency

The density of charged hadrons at $\eta \sim 0$ follows the trend from lower energies, which is linear in $\log \sqrt{s}$. CMS expected to see an averaged 4.2 charged hadrons in the central region. Meanwhile the averaged transverse momentum of charged hadrons at lower energies is described by a quadratic function in $\log \sqrt{s}$. The expected average p_T is about 0.7 GeV/c for CMS.



3 Underlying Events

The “underlying events” (UE) is everything in a single proton-proton interaction except for the hard scattering component. It’s not a minimum-bias event on top of the hard process. What happens to the beam remnants after the hard scattering is an important issue. The UE has the same production vertex so it’s tied to the process of interest. Its activity also grows with the process energy scale as a “pedestal effect”.

UE phenomenology has been studied with CDF data using “charged jet” from iterative cone algorithm on mass-less tracks. With various energy scale in p_T of the charged jet, multiplicity and p_T density has been studied in the transverse region. As we can easily tell from the following plots, the activities in this region have less influence from the hadron event.

Clear dependency on p_T can also be seen for charged jets in the toward region.

3.1 Underlying Event Models

The UE event modeling has both non-perturbative and perturbative aspects. The former ones include initial-state radiation (ISR), final-state radiation (FSR) and beam remnants together with multiple parton-parton interaction, while the later part have the following considerations: allowing more than one parton-parton interaction per pp-scattering (MPI); regularizing QCD two-to-two cross section cut-off on p_T , e.g. Pythia DW and DWT tunes; variable impact parameter models; and color reconnection models, e.g. Pythia S0. However, the current models based on Tevatron data have different behavior when extrapolating to LHC.

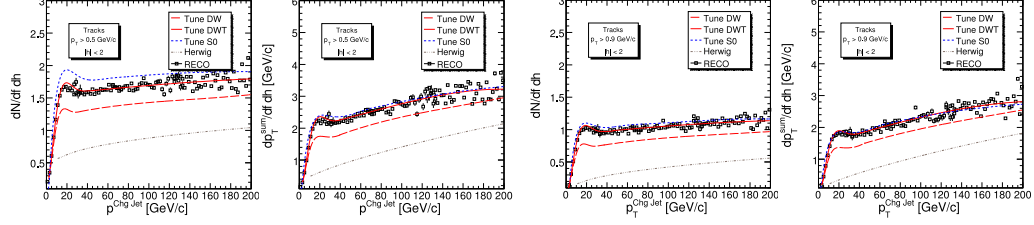
From an experimental point of view, one can use a topological structure of hadron-hadron collisions to probe the UE activities out of the hard scattering component. The activities near the transverse plane to the jet direction has the smallest influence from the hard scattering and provides the most sensitivity to the UE contributions.

3.2 Results

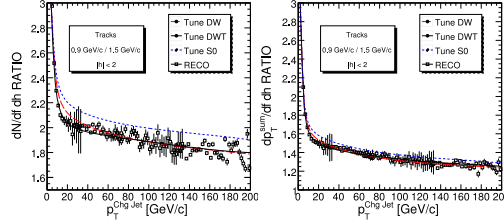
Herwig (without MPI), Pythia tunes DW, DWT, and with MPI), all predict observed results from the Tevatron. One can discriminate between these scenarios at LHC energies by looking at the density of charged particles $dN/d\eta d\phi$ and the momentum density $dp_T^{sum}/d\eta d\phi$ in the transverse region.

Density of charged particles and momentum of the leading charged particle jet using a track reconstruction threshold of 0.9 GeV/c is shown. Data points from different triggers are superimposed (Minimum Bias, JET20, JET60, JET120) and correspond to the corrected reconstruction level profiles using tune data). The lines correspond to the different generator level tunes: DW, DWT, S0 and HERWIG.

By lowering the p_T threshold to 0.5 GeV/c it is possible (largely due to MB data) to distinguish between DW/DWT and S0 as well.



With 100 pb⁻¹ of data it should be possible to discern between Herwig DW, and the two other Pythia tunes (DWT, S0) using a p_T threshold of 0.9 GeV/c.



4 Conclusion

The UE study can help us to discriminate between various QCD models which will facilitate the improvement and tuning of Monte Carlo models at LHC start-up. It will also open prospects for the exploration of QCD dynamics in proton-proton collisions at 10 TeV.

References

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